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Characteristics and oil sorption effectiveness of areca nut husk

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Abstract

Oil spill accident occur due to human carelessness and error during oil transportation, storage, and production of the hydrocarbon. Effect of oil spill can be either short or long term. It is not only affecting the environment but also marine life, economy, and social. Thus, effective recovery and control method must be carefully implemented to minimise the effect. There are various studies and technologies to mitigate the oil spill incident but mostly the techniques are very expensive, difficult and use of non-environmental friendly material. Hence, this study is conducted to study areca nut husk as a potential oil adsorbent for oil spill recovery. The characteristics of areca nut husk include morphological structures and chemical composition. The areca nut husk oil sorption effectiveness and capacity also been investigated. Areca nut husk were tested for both heavy crude oil and diesel adsorption. The result shows that the efficiency of oil sorption of areca nut husk toward heavy crude oil is 14.8% and it can be an alternative sorbent material to the current modern material. Meanwhile, the areca nut husk is not recommended to be used for diesel absorption activity for its low effectiveness (i.e., 2.04%) showed in this study.

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1.0 Introduction

Oil spill is defined as any accidental release of hydrocarbon liquid onto the environment during the oil production, transportation and storage (Bhardwaj & Bhaskarwar, 2018; Osamor & Momoh, 2015). Oil spill have become one of the most important study as it has both short and long-term disastrous effect on marine life, environment, and economy. Hydrocarbons released to the environment have been shown to be harmful to marine life at many organisational levels. It is estimated around 4.4 million barrels of crude oil were spilled over 84 days period during the Deepwater Horizon (DWH) incident in 2010 (Liu et al., 2016; Nyankson et al., 2016). Oil spills accident not only impacting the environment but also human health through inhalation, skin, and eye irritation.

To minimise the effect and controlling the oil spills, various oil spill response techniques have been used which can be categorised into mechanical, chemical, biological, and physical methods (Bhardwaj & Bhaskarwar, 2018). Mechanical methods include a variety of booms, barriers, skimmers, and sorbent materials. Meanwhile, chemical methods such as dispersants are used to reduce surface tension at the oil water interface which help creation of many small oil droplets.

Sorbents are type of materials that sorb oil either by absorption or adsorption or by their combination. Sorbents can be used for active oil removal, containment, and recovery of oil traces from land and water. They are classified into inorganic sorbents, synthetic organic, and natural organic sorbents (Hammouda et al., 2021). Additionally, sorbents may exist in different form, such as granules, woven and nonwoven fibres and particulate. Natural organic sorbent devices, especially agricultural waste is widely used because of its complete biodegradability, relative abundance of the resources and utilisation of the waste itself for pollution control. Furthermore, diverse treatment method can be used to improve the hydrophobicity and sorption capacity of natural sorbents (Bhardwaj & Bhaskarwar, 2018). Some example of organic natural adsorbent that been study previously are banana peel, human hair, and water hyacinth (Alaa El-Din et al., 2018; Ifelebuegu et al., 2015; Rodkong et al., 2016).

The areca nut husk is basically from areca palm tree (*Areca catechu*) and normally grow along on the coastal areas of South-East Asia countries

(Deshmukh et al., 2019; Sukla Baidya & Kumar, 2021). Areca nut fruits are divided into 3 types of maturity level which are raw, ripe, and matured fruits which can be differentiated by its physical appearance (Yusriah et al., 2014). The husk is the outer part of areca representing 15 to 30% of the raw areca nut which consisted of cellulose, hemicellulose, lignin, and pectin. Cellulose could be used as an adsorbent due to its good mechanical properties, non-toxic, and easy disposability after use (Suhas et al., 2016).

The objectives of this study are to identify the physical and chemical characteristic of areca nut husk and its absorbent capability. Besides that, the effectiveness of areca nut husk toward adsorption of crude oil and diesel where also determined.

2.0 Methodology

2.1 Material

Areca nut husk was obtained from local areas of Kuching, Sarawak, Malaysia where only well ripen were chosen. Firstly, the husk was cleaned with distilled water to eliminate any dust dirt, debris or unwanted particles that maybe effect the experiment result later. Then, the husk will be dried 24 hours at 180 °C in an oven for drying purpose.

Crude oil with API of 11 and diesel were chosen to analyse the oil sorption capacity of the sample. Both crude oil samples are obtained from Kemaman Bitumen Company in Malaysia. API represent the index of the density of a crude oil or refined products. Higher API indicates that the crude oil has low density. Therefore, crude oil used in this study are categorise as heavy crude oil since the API number is low with only 11.

2.2 Characteristics of areca nut husk

Morphological structures of areca nut husk were analysed using scanning electron microscope (SEM). Sample are examined with accelerating voltage of 15 kV and magnification of 300×, 500×, and 1000×. The diameter of sample was measured using a measuring tool bar as made available in the SEM computer program package. The surface, cross sectional area and void ratio of the fibres were determined from the image.

Next, the chemical composition was investigated using energy dispersive X-ray (EDX) spectrometer, one of SEM further. EDX have an electron-excited characteristic X-ray peaks that provide identification and quantification for all elements of the periodic table, with the exceptions of H, He, and Li. The type of constituents present in areca nut husk are used to determine the composition of cellulose, hemicellulose, and lignin in areca nut husk.

Fig. 1: Dried areca nut

2.3 Areca nut husk oil sorption effectiveness

The oil sorption effectiveness of areca nut husk was analysed by determining the storage density for adsorbent sample, water absorbency ratio and oil absorbency ratio. These tests were performed based on ASTM F726 standard test method for sorbent performance of adsorbents. According to the standard, areca nut husk is categorised as Type II adsorbent. Therefore, the conditions of the sample should be at 23 ± 4 °C and 70 ± 20% relative humidity for not less than 24 hours prior to testing.

The experiment was separated into three different tests in determining the oil sorption effectiveness which are dynamic degradation test, oil adsorption-short test and oil adsorption-long test.

2.3.1 Dynamic degradation test

This test was carried out to observe water take-up and to identify oleophilic properties of areca nut husk sample under dynamic conditions for 2 minutes. One gram of husk sample was placed in a 1 litre beaker which was half-filled with freshwater and sealed. The beaker was mounted on a shaker table. The frequency, amplitude, and duration of the shaker table were set at 150 cycles per minute, 3 cm, and 15 minutes, respectively. The condition of husk sample and condition of the water were recorded. The husk sample were drained for 30 second and then weighed. The water pick-up ratio was calculated. The steps were repeated using previous husk sample and 3 mL of oil was added in the beaker.

2.3.2 Oil adsorption -short and long test

Four grams of areca nut husk was weighed before being submerged into a beaker filled with crude oil with an equal depth of the thickness of the adsorbent. The adsorbent was lowered into the beaker and allowed to float freely within the beaker. For the short adsorption test, the areca nut husk was submerged for 15 minutes, while for long test, it took 24 hours before the sorbent was removed from the beaker before weighing.

All tests were duplicated three times to get the average value. The oil pick-up ratio on weight basis was calculated, to represent the volume of oil per adsorbent sample. The procedure was repeated using diesel oil for comparison. Oil adsorption capacity effectiveness for both crude oil and diesel were obtained from the equation (1) below:

$$Sorption\ capacity\ effectivenees = \left(\frac{x_0 - x_s}{x_s}\right) x\ 100 \quad (1)$$

where x_o is the total mass of wet sorbent after oil adsorption and x_s is the mass of the mass of the adsorbent before adsorption.

3.0 Results and discussion

3.1 Characteristic of areca nut husk

The SEM micrograph shown in Fig. 2 is the image of areca nut husk with 300- and 1000-times magnification. The lumen size and structures of areca nut husk can be clearly seen. The image revealed that the surface of the areca nut husk is rough and there are uneven pores which can provide a great surface area for oil adsorption.

Theoretically, the size of the lumen in natural fibre is proportional to the diameter, where the lumen size increase with the increase in fibre diameter (Baley, 2002). As shown in Fig. 1, the areca nut husk fibre was observed bigger lumen size that easy for absorbed liquid via lumen into the fibre cell wall.

In terms of chemical composition, the EDX analysis revealed that the areca nut husk consists of two main elements which are carbon 57.3 wt.% and oxygen 31.1 wt.%. The FTIR analysis of areca nut husk is shown in Fig. 3. The peaks indicate a different wavelength which represent various functional groups of areca nut husk. The band in the region of 3265.47 cm^{-1} indicated the presence of a stretching of strong hydroxyl (–OH) groups (Ahmaruzzaman & Gupta, 2011; Saravanan et al., 2013). The peak at 2917.01 cm^{-1} was due to stretching from the alkyl (–CH_2) group and peak at 1629.12 cm^{-1} represent the (–C=O) stretching from the carboxyl (–COOH) group (Devaraj et al., 2016; Priya et al., 2014). In addition, the band at 1232.20 cm^{-1} corresponds to C–O stretching which indicate the lignin band. The present of (–OH) and (–C–H) groups indicate the presence of cellulose and lignin.

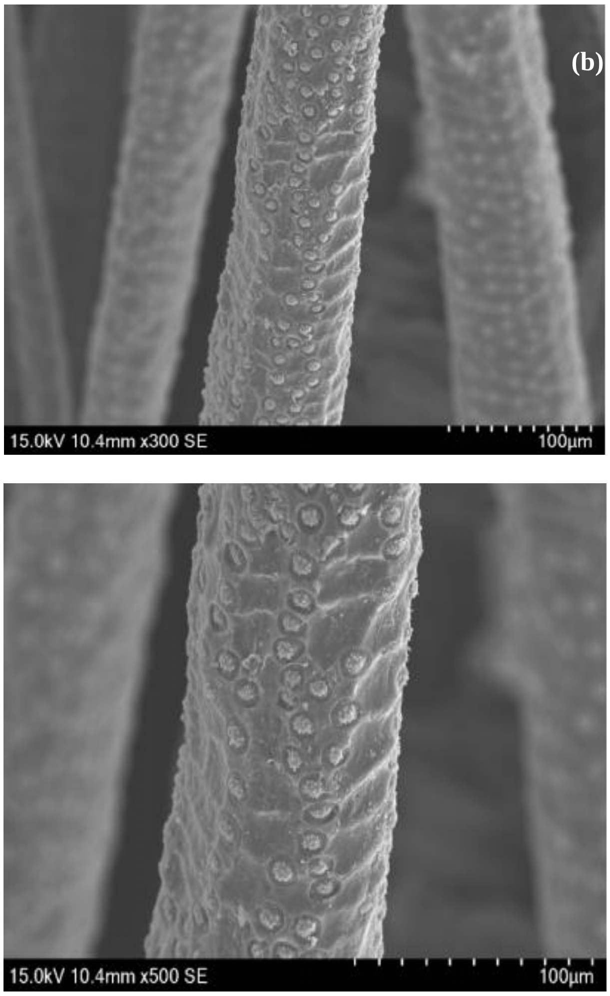

Fig. 2: SEM micrograph of Areca nut husk (a) with magnification of 300× and (b) 1000×

3.2 Oil sorption effectiveness of areca nut husk

The oil sorption effectiveness of areca nut husk was measured on the average value from three tests as explained earlier. Degradation test was carried out to observe the water take-up and identify oleophilic properties of areca nut husk sample under dynamic condition. Based on the ASTM 726-99 standard, if 10% of the sorbent sink to the bottom of the liquid then the sorbent was deemed to fail the test. From the experiment observation, the areca nut husk had shown good floating mechanism as none of the sorbent were sunk to the bottom of the beaker and it prove that the experiment conducted are well tested. From the dynamic degradation test, the water showed an absorbency of 7.27%. These indicated that the amount of water been absorbed by areca hut husk before been exposed to crude oil or diesel.

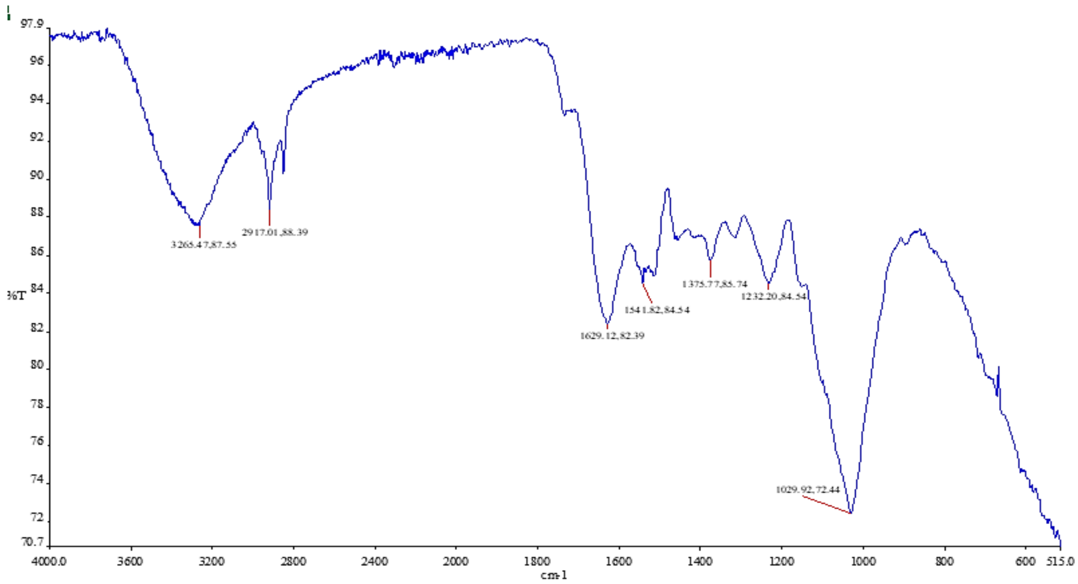

Fig. 3: The FTIR spectrum of areca nut husk

Table 1: Comparison between heavy crude oil and diesel

Type of oil	Heavy Crude Oil	Diesel
Oil Adsorbency Short Test (%)	14.8%	5.65%
Oil Adsorbency Long Test (%)	16.25%	4.92%
Oil / water ratio Short test (%)	2.04%	0.78%
Oil / water ratio Long test (%)	2.24%	0.68%

Table 1 shows the adsorption capacity of areca nut husk toward crude oil and diesel oil. For adsorption short and long test, oil absorbency for heavy crude oil is 14.8% and 16.25%, respectively. Meanwhile for the oil to water ratio for short and long test of heavy crude oil are 2.04% and 2.24%, respectively. These indicated that water absorbed earlier by the areca nut husk effect the performance of sorption capacity.

Meanwhile for diesel adsorption capacity for short and long test are 5.67 % and 4.92%, respectively. The same goes for crude oil, the oil to water ratio of diesel for short and long test showed a decrease to 0.78% and 0.68%, respectively. Looking at the absorption capability for diesel, it is not recommended for areca nut husk to be used for diesel sorption purpose due to its low absorption capability with only less than 1 % of weight can be absorbed. This is because the viscosity of the diesel is lower than heavy crude oil that reduce the capability to be absorb by the areca nut husk. Compared to other nature organic material from past research it shows that areca nut husk is moderately suitable for heavy crude oil adsorption since the absorption is between kapok fibre and sugarcane bagasse (Ali et al., 2011; Osamor & Momoh, 2015).

4.0 Conclusions

Areca nut husk exhibits good oil sorption capabilities effectiveness for crude oil with sorption capacities exceed 10% of weight without the presence of water. But if the water were present, the effectiveness to absorb reduce to 2% of weight. Meanwhile it is not recommended to used areca nut husk for diesel application because of its low absorption capability. Further study on the capability of areca nut hunk maybe can be conducted such as its absorption capability if mix with other natural organic material such as kapok fibre, sugarcane bagasse. Sea water as the medium also can be substitute with distill water that been currently used in this experiment.

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